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Review

An overview on the role of virus vectors in host plant Intraction-transmission strategy

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Viruses are submicroscopic infectious particles that cause many important plant diseases. Plant viruses rarely come out of the plant and cannot be disseminated as such by wind or water, but they are being transmitted from plant to plant in a number of ways and by living organisms called vectors. This article attempts to show the relationship between Vectors and Viruses in host plant infection. It discusses the transmission of viruses by vectors from unhealthy host plants to healthy host plants to cause infection. Each successive step of vector-virus transmission is needed for transmission to be successful. Different modes of virus transmission are characterized based on the retention time, sites of retention, and internalization of virions by vectors. It goes further to discuss the specificity of transmission of a virus by a vector as a critical factor in vector-virus interaction. It concludes that transmission from host to host by vectors is an important step in the biological cycle of plant viruses to ensure their maintenance and survival. Therefore the control of virus vectors is an effective way of controlling viral diseases of crop to ensure sustainable productivity of crops.

Key words: Vectors, virus transmission, host plant infection, vector-virus interaction, specificity.

INTRODUCTION

Viruses are very small (submicroscopic) infectious particles (virions) composed of a protein coat and a nucleic acid core (Dickinson, 2005). They cause many important plant diseases (Strange, 2003) and are responsible for huge losses in crop production and quality in all parts of the world. In other words, Plant viruses can cause severe yield losses to the cereal, vegetable, fruit, and floral industries, and substantially lessen the quality of crop products (Andret-Link and Fuchs, 2005; Agrios, 2014).

Plant viruses rarely come out of the plant and it should therefore be noted that they cannot be disseminated as such by wind or water, but they are being transmitted from plant to plant in a number of ways such as; vegetative propagation, mechanically through cell sap, seed, pollen, insects, mites, nematodes, dodder and fungi, man, wind and ants (Singh, 2005; Mehrotra and Aggarwal, 2010; Agrios, 2014; Pandey, 2012). However, the most common and economically most important means of transmission of viruses in the field is by insect vectors (Pandey, 2012).

Plant-feeding arthropods, nematodes and plant-parasitic fungi are the major types of vector organisms for plant viruses (Walkey, 1991). Only relatively few viruses, such as TMV, rely on long-term (up to decades) survival in the environment and on passive mechanical transmission from plant to plant (Ford and Evans, 2003). The living organisms that actively transmit viruses are called vector. Knowledge of the role of virus vectors in host plant infection is necessary for the control of viral diseases. Therefore this article attempts to show the relationship between virus and vector in host plant infection, the transmission modes and the characteristics of vector-virus transmission for use in plant disease management.

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Vector-virus transmission and host plant infection

Many viral diseases depends on insects vectors for transmission between host plants, e.g. maize streak virus disease (Ramusi and Flett, 2012). Vectors of plant viruses are taxonomically very diverse and can be found among arthropods, nematodes, fungi, and plasmodiophorids (Froissart et al., 2002; Hull, 2002). Arthropod vectors that transmit most plant viruses are aphids, whiteflies, leafhoppers, thrips, beetles, mealy bugs, mirids, and mites (Spence, 2001), the most common being aphids with more than 200 vector species identified (Ng and Perry, 2004). More than half of the nearly 550 vector transmitted virus species recorded so far are disseminated by aphids (55%), 11% by leafhoppers, 11% by beetles.

Vector-virus transmission consists of several successive steps: acquisition of virions from an infected source, stable retention of acquired virions at specific sites through binding of virions to ligands, release of virions from the retention sites upon salivation or regurgitation, and delivery of virions to a site of infection in a viable plant cell. Each step of this sequence is needed for transmission to be successful (Andret-Link and Fuchs, 2005). According to Andret-Link and Fuchs (2005), a single mode of transmission is characteristic of most viruses, features of the different modes of virus transmission are important for transmission specificity and the different modes of virus transmission are characterized based on the acquisition and retention time, sites of retention, and internalization of virions by vectors.

After a successful transmission, infected plants may show a range of symptoms depending on the type of disease, but often there is leaf yellowing (either of the whole leaf or in a pattern of stripes or blotches), leaf distortion (e.g. curling) and/or other growth distortions (e.g. stunting of the whole plant, abnormalities in flower or fruit formation) (Strange, 2003; Dickinson, 2005; Pandey, 2012; Agrios, 2014).

Vector-virus interaction in host plant infection

The virus-vector relationships are of several types. At one extreme, the association occurs within the feeding apparatus of the insect, where the virus can be rapidly adsorbed and then released into a different plant cell. The feeding insect looses the virus rapidly when feeding on a non-infected plant (Ramusi and Flett, 2012; Agrios, 2014). Such a relationship is termed "non-persistent" (Strange, 2003). The best studied examples are of potyvirus transmission by aphids (Andret-Link and Fuchs, 2005).

At the other extreme, the virus is taken up into the vector, circulates within the vector body and is released through the salivary glands. The vector needs to feed on an infected plant for much longer and there is an interval (perhaps several hours) before it can transmit (Strange, 2003; Andret-Link and Fuchs, 2005; Dickinson, 2005). Once it becomes viruliferous, the vector will remain so for many days, such a relationship is termed "persistent" or "circulative" (Strange, 2003). The best studied examples are of luteovirus transmission by aphids. In some examples of this type (e.g. some hoppers and thrips), the virus multiplies within the vector and this is termed "propagative" (Strange, 2003).

Nonpersistent viruses are retained by their vectors for a few hours, whereas semipersistent viruses are retained for days, weeks, or even months. Viruses in these two categories are acquired from infected plants and inoculated within seconds or minutes to recipient plants. In addition, they do not require a latent period, e.g. time interval between acquisition and transmission, and do not replicate in the vector. Nonpersistent and semipersistent viruses are specifically associated with the epicuticle that lines the stylets (mouthparts) or the foreguts of their arthropod vectors, respectively, or the cuticle lining of the feeding apparatus of their nematode vectors. Since the cuticle, including the lining of the mouthparts and foregut, is shed during molting, acquired viruses are lost at each molt (Strange, 2003; Andret-Link and Fuchs, 2005).

Collectively, the nonpersistent and semipersistent viruses are referred to as noncirculative because they are not internalized by vectors. In other words, they do not enter the hemocoel (vector body cavity) or cross any vector cell membrane (Gray and Banerjee, 1999). Persistent viruses, once acquired from infected plants, are associated with the vector for the rest of their lifetime. They require long acquisition times (ranging from hours to days) and long latent periods (ranging from one day to several weeks). Successful transmission of persistent viruses requires an internalization of the ingested viruses that are actively transported across several cell membranes. Thus, they are found in the hemocoel of vectors and retained by vectors after molting (Andret-Link and Fuchs, 2005).

Ultimately, they must associate with the vector salivary system to be transmitted into a new host. Persistent viruses are referred to as circulative. They are further divided into propagative, e.g. viruses that replicate in their arthropod vectors in addition to their plant hosts, and nonpropagative viruses, e.g. viruses that replicate only in their plant hosts but not in their vectors (Gray and Banerjee, 1999).

Significant progress has been made over the last two decades on the interaction between viruses and their vectors through biological, biochemical, and molecular studies. For some viruses, new advances have been possible through the development of pseudo-recombinant isolates that have one RNA from one virus isolate combined with the RNA of a different isolate of the same virus or a different virus. Also, hybrid isolates have been developed with some genes derived from one virus or isolate and other genes from another virus or another isolate from the same virus. Recent advances have also been possible through molecular studies based on reverse genetics and mutagenesis, or by comparative sequence analysis of vector transmissible viruses and transmission deficient mutants (Andret-Link and Fuchs, 2005).

Characteristics of a vector-virus interaction

The transmission of a virus by a vector is often characterized by some degree of specificity (Dickinson, 2005; Andret-Link and Fuchs, 2005; Gergerichand Dolja, 2006), in other words, most viruses are restricted to a particular type of host (Andret-Link and Fuchs, 2005). There are no individual virus species that are capable of being transmitted by insects from more than one family (Dickinson, 2005).Transmission specificity can be broad or narrow, but it is a prominent feature for numerous viruses and vectors. Specificity of transmission is this case is the specific relationship between a plant virus and one or a few vector species but not others (Andret-Link and Fuchs, 2005). For instance, a virus transmitted by aphids is not transmitted by nematodes or among arthropod vectors; a virus transmitted by leafhoppers is not transmitted by beetles. An extreme case of transmission specificity is exclusivity, when a vector transmits one virus or one serologically distinct virus strain, and this virus or virus strain has a single vector. As examples of the different degrees of specificity, (GVLV) Grape vine leaf virus is naturally transmitted by a single nematode species, *Xiphinema index*, while some potyviruses are transmitted by more than 30 aphid species (Jeger et al., 2004). Also, the whitefly (*Bemisia tabaci*) transmits numerous viruses from various genera and families, while the beat lace bug (*Pisemaquadratum*) transmits only beet leaf curl virus (BLCV). In contrast, closteroviruses are transmitted by aphids, mealybugs, or whiteflies, whereas tobraviruses are transmitted only by trichodorid nematodes (Andret-Link and Fuchs, 2005). The specificity of transmission is explained by several characteristics, including a recognition event between the virion, or a viral protein motif, and a site of retention in the vector (Brown and Weischer, 1998). Below are names, acronyms, genus and families of plant viruses indicating their specific host plants were listed by Andret-Link and Fuchs (2005). For instance; wheat streak mosaic virus WSMV, Tritimovirus, Potyviridaetles, 9% by whiteflies, 7% by nematodes, 5% by fungi and plasmodiophorids, and the remaining 2% by thrips, mites, mirids, or mealybugs (Astier et al., 2001).

Extensive information is available on viral determinants of transmissibility but limited information is available yet on viral determinants of transmission specificity. The coat protein (CP), or its derivatives (read-through CP and minor CP), and nonstructural proteins, including a helper component (HC) or a transmission factor (Pirone and Blanc, 1996) are involved in transmission specificity. Numerous comprehensive reviews have been recently published on virus transmission by arthropods (Gray and Banerjee, 1999), including aphids (Ng and Perry, 2004), Olpidium and plasmodiophorid vectors (Campbell, 1996; Kanyuka et al., 2003; Rochon et al., 2004), and nematodes (McFarlane, 2003).

CONCLUSION

Most plant virus species (88%) use an arthropod vector as a mean of transportation from one host to another. Transmission is often characterized by some degree of specificity, and numerous findings indicate the possible involvement of a specific ligand/receptor interaction. Transmission mechanisms are remarkably different between plant viruses, with no correlation with genome type, particle morphology, or strategy of viral protein expression, and transmission from host to host by vectors is an important step in the biological cycle of plant viruses to ensure their maintenance and survival (Andret-Link and Fuchs, 2005), as such, the control of virus vectors that transmit a particular viral disease to a particular crop is an effective way of controlling that viral disease, thereby ensuring sustainable productivity of that crop.

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